Response to "ZCache Skew-ered"

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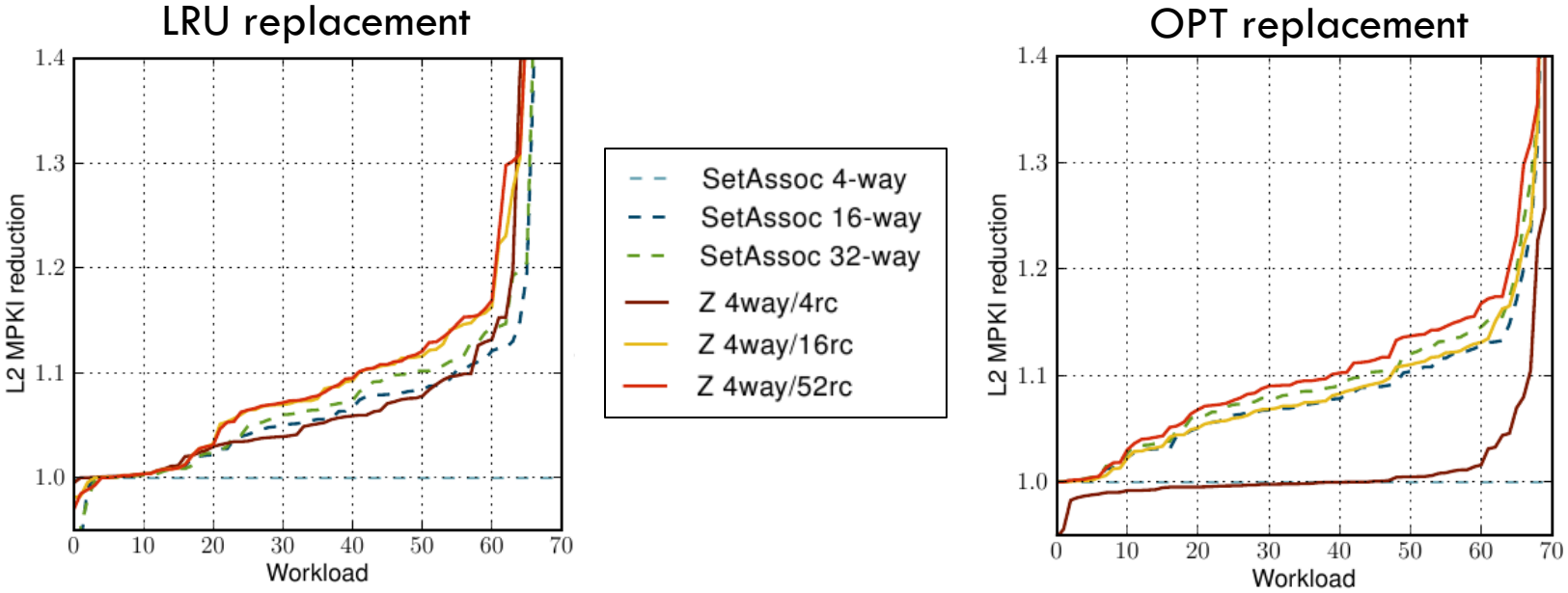
Summary

- Thanks for deconstructing ZCache!

- Clarifications:
  - Multi-level replacement does increase associativity
    - Your simulations do not exploit high associativity
  - Hash function quality deserves further exploration
    - Your simulations do not stress hash function quality

Multi-level Replacements

- ZCache MICRO paper already shows little benefit from >16 replacement candidates when using LRU



- Multi-level replacement does increase associativity
- LRU cannot exploit the extra associativity

Associativity Distributions

- Associativity can be characterized independently of replacement policy, using probability distributions

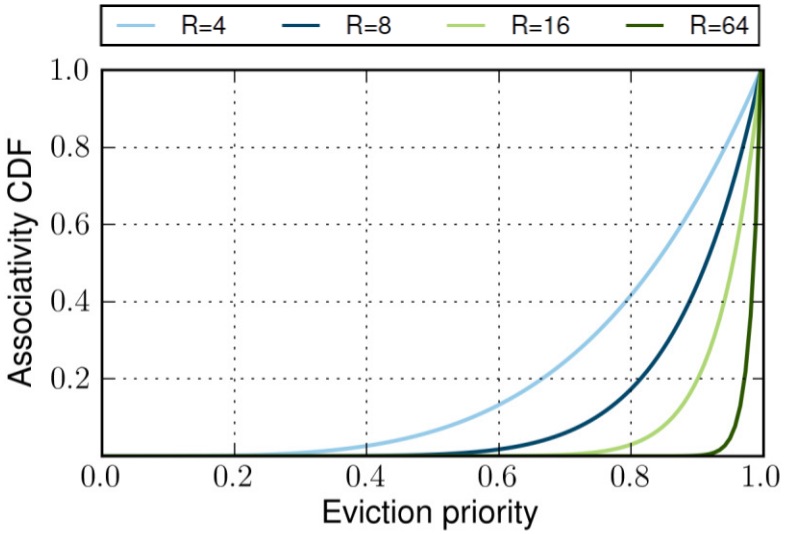
- Eviction priority: Rank of a line given by the replacement policy, normalized to [0,1]
  - Higher priority → better to evict
  - e.g. with LRU policy, LRU line has 1.0, MRU line has 0.0 priority

- Associativity distribution: Probability distribution of the eviction priorities of evicted lines
  - Higher associativity ←→ distribution more skewed towards 1.0
  - Decouples associativity from replacement policy
    - For good performance, replacement policy needs to do a good job ranking!

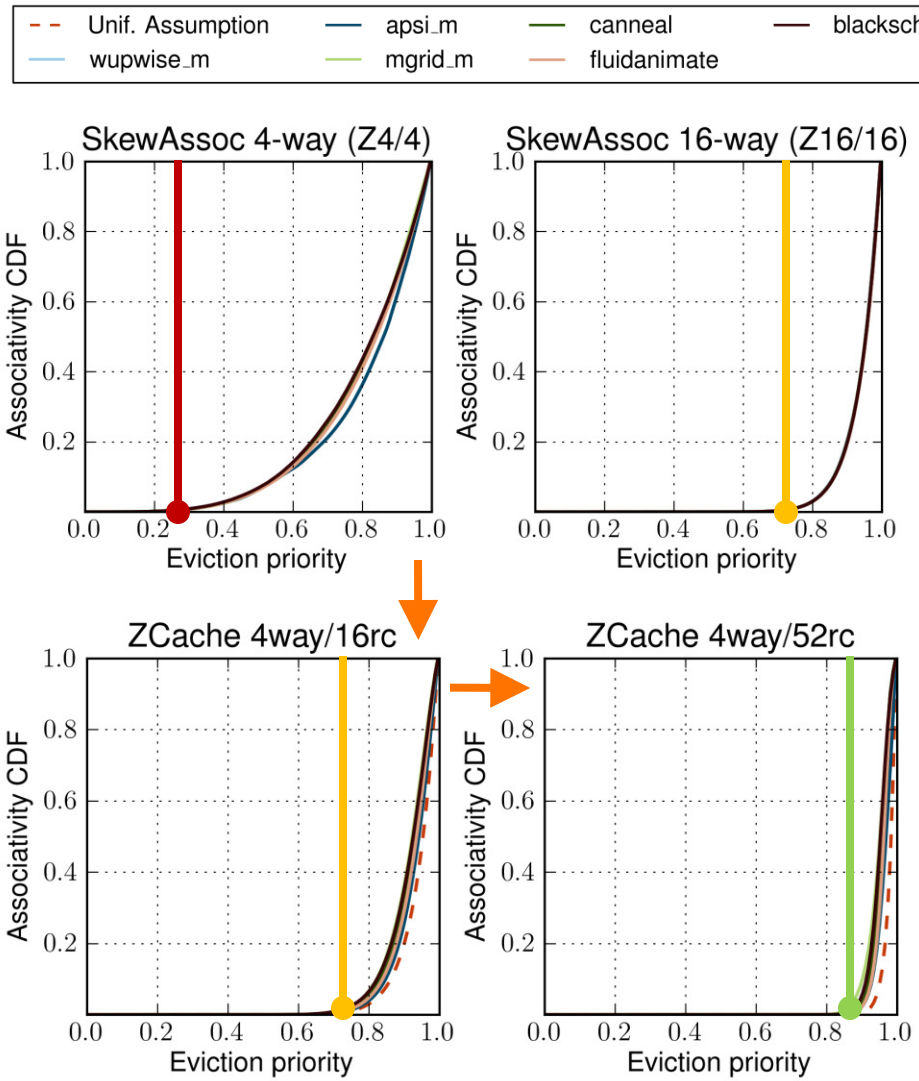
Uniformity Assumption

- Due to good hashing, zcaches give close to uniformly distributed replacement candidates (R)
- In this case, can derive the associativity distribution:

$$F_A(x) = P(A \leq x) = x^R, \; x \in [0,1]$$



Associativity Distributions for ZCaches



- Skew-associative caches are very close to UA
- Increasing candidates but not ways still yields distrib very close to UA

Associativity Distributions: Conclusions

- In caches with good hashing, the number of replacement candidates determines associativity
  - Increasing candidates as beneficial as increasing ways
- ZCaches provide large number of candidates with few ways → Decouple ways and associativity
- How to leverage high associativity?
  - Better replacement policies (e.g. RRIP instead of LRU)
  - Vantage cache partitioning [ISCA 2011] (talk tomorrow!)

Hash Function Quality

- Hash function quality was not the point of zcache
  - Chose H3 because they are high-quality and cheap
  - Good to see that simpler hash functions work well, but…
- H3 functions have two desirable properties:
  - Universal → uniform distribution of hash values
  - Pair-wise independent → the quality of replacement candidates does not degrade with the number of levels
- Skewing hash functions do not have these properties
  - Problem: Your simulations do not exploit multi-level replacement benefits → insensitive to hash quality issues

Conclusions

- We stand by our claim: ZCaches decouple ways and associativity
  - LRU does not benefit from high associativity
  - Better replacement policies, Vantage partitioning do
- Skewing functions work well for 1,2-level replacements
  - But with multiple levels, higher-quality hash functions may be worth the minimal extra cost

THANK YOU FOR YOUR ATTENTION

QUESTIONS?